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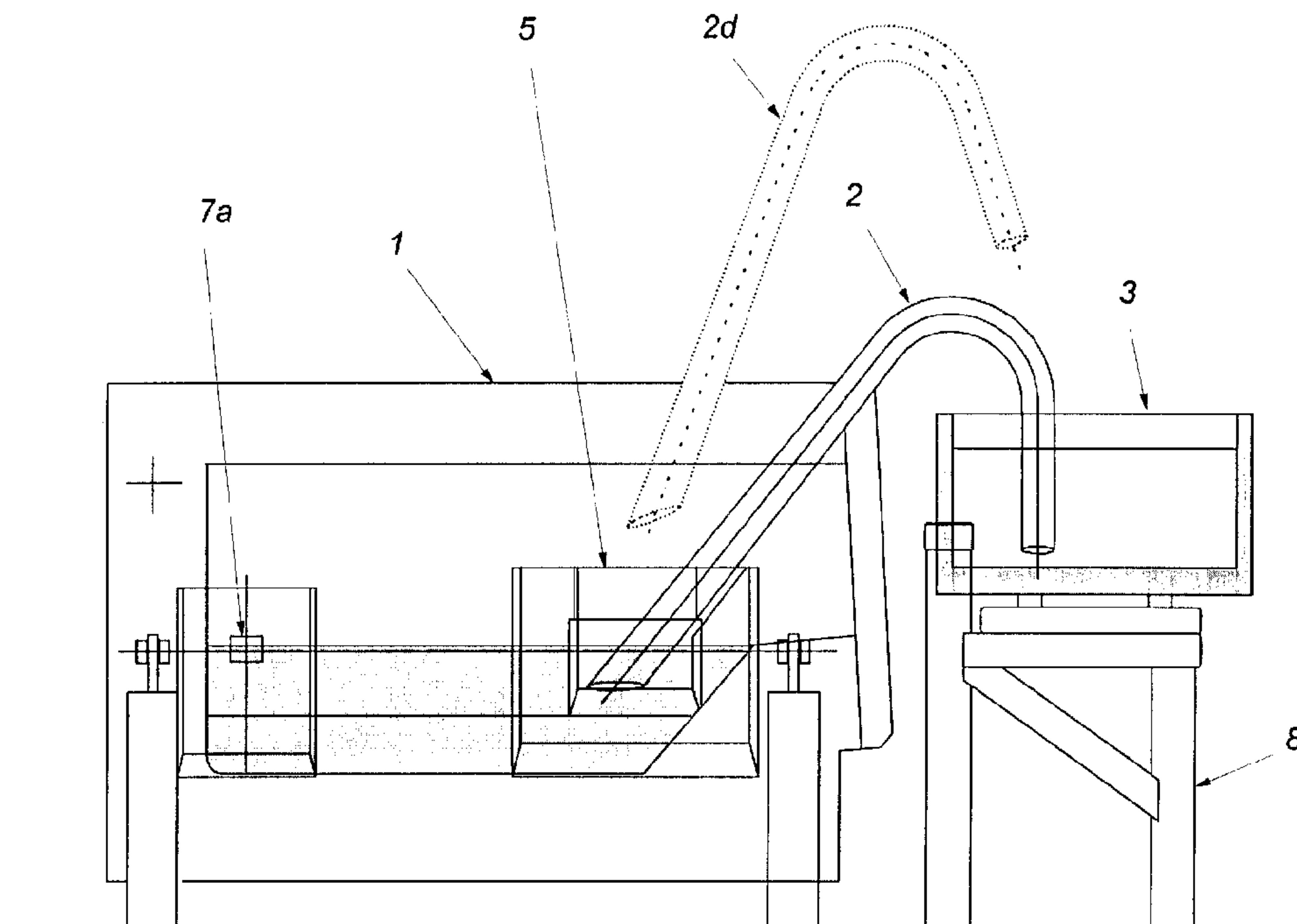
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(54) Titre : APPAREIL ET PROCEDE D'ALIMENTATION EN METAL FONDU
(54) Title: APPARATUS AND METHOD FOR THE SUPPLY OF MOLTEN METAL



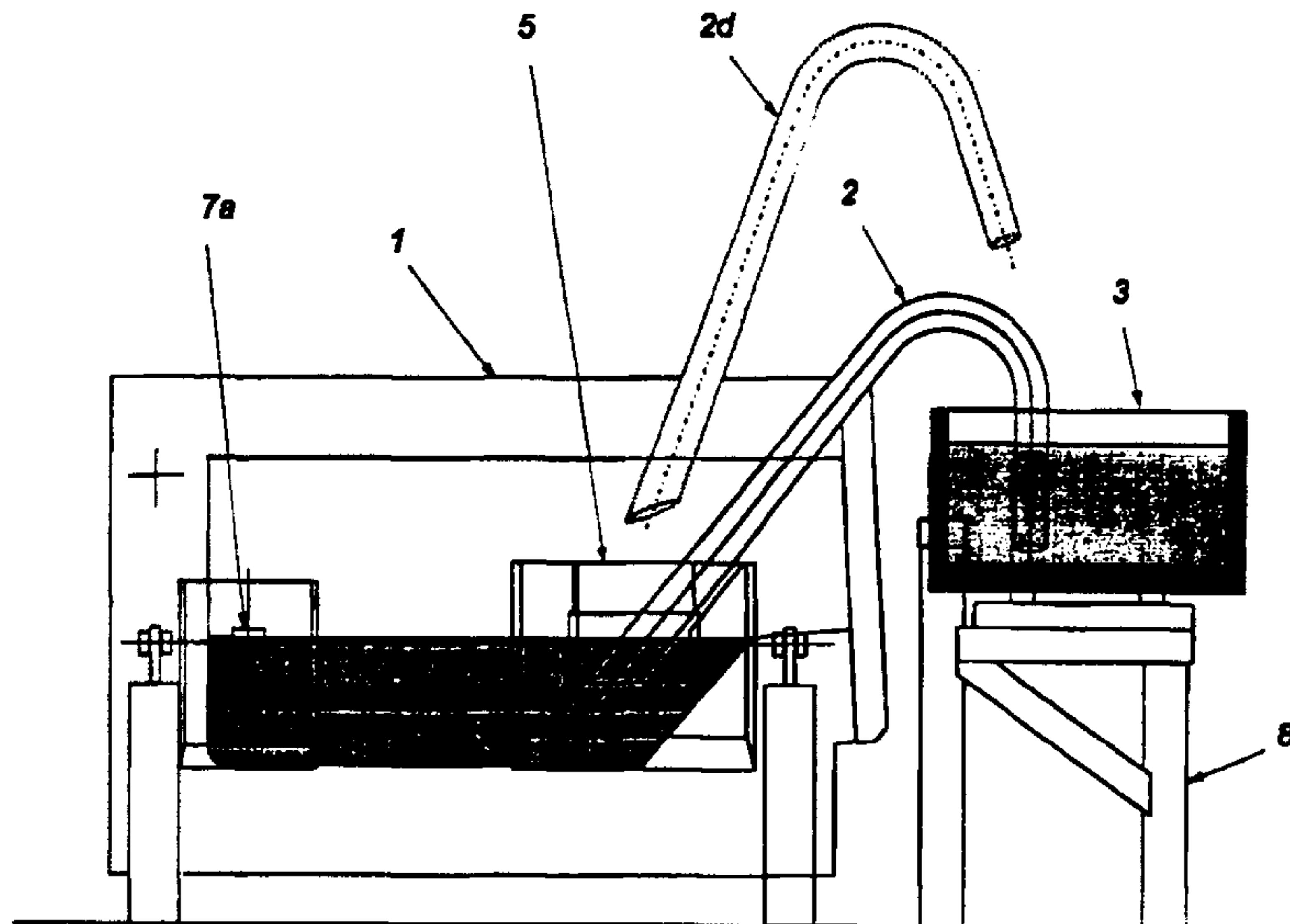
(57) Abrégé/Abstract:

A holding furnace (1) for supplying molten metal to a casting launder (11) is disclosed including a metal chamber (9), an outlet (7a) from said metal chamber and an inlet well (5) positioned on the holding furnace (1) on or adjacent to the pivot axis (4) of the holding furnace. The inlet well is axially displaced along the pivot axis from the outlet (7a) of the holding furnace so that the motion of molten metal entering through the inlet well does not disturb the level of molten metal in the launder (7). The holding furnace (1) may be incorporated into an apparatus for supplying molten metal to a casting launder preferably including a transfer conduit (2) having one end submerged below the level of metal in the inlet well and the other end submerged below the level of metal in a molten metal source (3). The flow of metal into the inlet well is controlled to minimize turbulence and allow the holding furnace to supply a steady, continuous flow of metal to a launder (7) while being intermittently charged with molten metal from the molten metal source (3).

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(54) Title: APPARATUS AND METHOD FOR THE SUPPLY OF MOLTEN METAL



(57) Abstract

A holding furnace (1) for supplying molten metal to a casting launder (11) is disclosed including a metal chamber (9), an outlet (7a) from said metal chamber and an inlet well (5) positioned on the holding furnace (1) on or adjacent to the pivot axis (4) of the holding furnace. The inlet well (5) is axially displaced along the pivot axis from the outlet (7a) of the holding furnace so that the motion of molten metal entering through the inlet well does not disturb the level of molten metal in the launder (7). The holding furnace (1) may be incorporated into an apparatus for supplying molten metal to a casting launder preferably including a transfer conduit (2) having one end submerged below the level of metal in the inlet well and the other end submerged below the level of metal in a molten metal source (3). The flow of metal into the inlet well is controlled to minimize turbulence and allow the holding furnace to supply a steady, continuous flow of metal to a launder (7) while being intermittently charged with molten metal from the molten metal source (3).

TITLE: APPARATUS AND METHOD FOR THE SUPPLY OF MOLTEN METAL

Technical Field of the Invention

This invention relates to the supply of molten metal from a holding furnace to a casting launder and in particular to an apparatus and process which enables the supply of molten metal to continue while the holding furnace is being recharged. The invention also relates to a process for refilling the holding furnace of the invention and the batch operation of the apparatus.

Background of the Invention

During the casting of molten metals such as aluminium, a holding furnace is tilted to maintain a constant level in the casting launder. The level in the launder is usually automatically controlled by sensing the launder metal level and tilting the furnace by adjusting the flow of hydraulic fluid to the furnace tilting cylinder(s).

In conventional arrangements where the holding furnace is filled by pouring, a charging port shaped like an angled funnel is often used to direct the molten metal poured from a spout on the transport crucible through the furnace wall above the maximum metal level. Where the furnace is filled by siphoning, the siphon pipe is usually suspended from an overhead hoist with the delivery leg of the pipe passing through a hole in the wall of the furnace above the maximum metal level. Where a charging port is employed, it is usually located to suit the delivery point of the transport crucible and to avoid furnace equipment such as burners and access doors.

This type of conventional charging arrangement will not normally permit the furnace to be tilted during a charging operation. While the furnace is continually tilting about the tilt axis during the casting operation, it is technologically difficult and would require complex equipment to be able to charge fresh molten metal to the holding furnace during a casting operation.

Consequently, once the holding furnace is emptied, it is returned to its upright position and refilled by either pouring or as has been suggested, siphoning molten metal from the potline crucible which supplies molten metal.

To provide a casting operation with a continuous supply of molten metal, it is necessary to have two holding furnaces arranged to feed into a common launder

system. While this results in a duplication of supply apparatus, and increased capital cost, it allows one furnace to supply the casting operation, while the other furnace is being filled.

Disclosure of the Invention

It is an object of the present invention to provide a method of supplying molten metal and an apparatus for the supply of molten metal which enables intermittent charging while maintaining a constant supply of molten metal to the casting process.

Accordingly, the invention provides a method of supplying molten metal including the steps of providing a holding furnace for molten metal pivotable about a pivot axis, tilting said holding furnace about the pivot axis for the supply of molten metal to a casting process from an outlet in the holding furnace via a launder, intermittently charging a controlled flow of molten metal to an inlet well communicating with a metal chamber in the holding furnace and positioned on the holding furnace on or adjacent to the pivot axis of the holding furnace, the inlet well being axially displaced along the pivot axis from the outlet of the holding furnace and controlling the tilting of the holding furnace to maintain the level of molten metal in the launder at a predetermined level.

By maintaining the level of molten metal in the launder at a predetermined level, a constant supply of molten metal can be maintained to the casting process.

Preferably the tilting of the holding furnace is controlled by monitoring the level of molten metal in the launder and adjusting the tilt angle of the holding furnace to maintain a predetermined level of molten metal in the casting launder.

In a preferred form of the invention, the molten metal is charged into the inlet well of the holding furnace from a crucible. The level of molten metal in the crucible is preferably above the level of molten metal in the inlet well to enable the metal to be transferred from the crucible to the inlet well by a conduit. The conduit is preferably shaped like an inverted "U" with the receiving leg being shorter than the discharge leg.

To effect the transfer of molten metal, the receiving leg of the conduit is preferably lowered into a transport crucible whilst the discharge leg is placed into

the furnace inlet well. Both legs of the conduit preferably remain submerged in molten metal and the metal level in the crucible must remain above the metal level in the furnace during the transfer process.

In this way, the curved section of the U-shaped conduit forms a weir in which the molten metal must rise up the receiving leg into the curved section above the weir point before being able to flow down the discharge leg of the conduit into the furnace inlet well. To cause the molten metal to rise up the conduit, a vacuum is applied to the conduit by the connection of a vacuum line to a tapping in the curved section of conduit. Provided the curved section of conduit does not completely fill with molten metal, the flow rate of the molten metal may be controlled by controlling the vacuum in the conduit. Once the curved section of conduit completely fills with molten metal, the conduit acts as a conventional siphon and the flow rate is then governed by the head of molten metal and the flow parameters of the conduit, resulting in the flow becoming uncontrollable.

Further detail of the operation and control of the metal transfer conduit is provided in the applicant's co-pending International publication WO96/06319, entitled "Transfer of Molten Metal".

The transfer conduit is preferably aligned substantially co-planer with the pivot axis of the holding furnace. During transfer, the position of the transfer conduit relative to the holding furnace is fixed so that the whole of the conduit pivots about the pivot axis of the holding furnace. Since the supply crucible is stationary during metal transfer and does not pivot with the holding furnace, it is preferable that the transfer conduit is free to move within the crucible to compensate for the tilting movement of the holding furnace and transfer conduit during charging of the holding furnace relative to the stationary crucible.

Another aspect of the invention provides an apparatus for the supply of molten metal including a holding furnace pivotable about an axis having a metal chamber for holding molten metal, an outlet for supplying molten metal from said metal chamber and an inlet well communicating with said metal chamber, said inlet

well being positioned on or adjacent the pivot axis of the holding furnace and displaced along the pivot axis from said outlet, a charging means for intermittently supplying a controlled flow of molten metal to the inlet well of the holding furnace, and a control means for varying the degree of pivot of the holding furnace to maintain a predetermined supply rate of molten metal.

To ensure that the discharge leg of the conduit remains submerged during metal transfer it is preferable that the base of the inlet well is positioned below the level of the molten metal in the metal chamber throughout the full range of pivotal motion of the furnace.

Preferably the above apparatus further comprises a furnace tilt hoist for raising or lowering one side of the holding furnace causing the furnace to pivot about the pivot axis. In its preferred form the tilt hoist is an hydraulic cylinder.

The control means may include a control device which continuously monitors a signal from a level sensor in the launder, the control device causing the tilt hoist to adjust the degree of tilt of the holding furnace to maintain the molten metal in the launder at a predetermined level.

The applicants have found that by controlling the transfer of molten metal to limit the flow rate into the inlet well of the holding furnace, additional advantages of the invention such as reduced dross formation can be realised.

In the preferred form of the invention, the charging means for intermittently supplying a controlled flow of molten metal to the inlet well of holding furnace may be a transfer conduit supplying molten metal from a removable supply vessel.

The position of the conduit relative to the holding furnace and inlet well is preferably fixed during charging and is aligned in line with the pivot axis of the holding furnace. In this way, there is no relative movement of the conduit in the inlet well of the holding furnace as the furnace goes through its tilt cycle. However, since there is relative movement between the crucible and the end of the transfer conduit, the crucible is preferably positioned to enable relative movement of the conduit without affecting the transfer of molten metal and to avoid contact between the conduit and the crucible.

The conduit is preferably shaped like an inverted "U" with the receiving leg

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being shorter than the discharge leg. To effect transfer of the molten metal from the crucible, the receiving leg of the conduit is preferably lowered into a crucible whilst the discharge leg is placed into the furnace inlet well. Molten metal is drawn up the receiving leg of the conduit above the level of molten metal in the crucible preferably by connection of a tapping in the "U" or curved section of the conduit to a vacuum line and applying a vacuum in the conduit. The level of molten metal in the crucible is preferably above the level of molten metal in the inlet well to enable transfer to be effected.

As long as the "U" or curved section of the conduit is not completely filled with molten metal, the "U" or curved section functions as a weir and the flow rate of molten metal over the weir can be controlled by adjusting the vacuum in the conduit.

As discussed earlier, further details of the apparatus and operation for transferring molten metal in a transfer conduit are disclosed in the above-mentioned co-pending International Publication WO96/06319.

The present invention enables the holding furnace to be charged while maintaining a supply of molten metal to an operation such as a casting operation. Therefore only one holding furnace is required per casting station. Additionally, dross formation is reduced by the preferred form of the invention thereby compounding the cost savings of the invention.

The invention in a further aspect provides a holding furnace for the supply of molten metal including a tilt hoist for tilting the furnace about a pivot axis, a metal chamber for holding molten metal, an outlet for supplying molten metal from said metal chamber, said outlet being positioned on or about the pivot axis, and an inlet well for intermittently receiving molten metal from a molten metal source, said inlet well communicating with said metal chamber to enable molten metal to flow to said metal chamber and being positioned on or about the pivot axis of the holding furnace, displaced along the pivot axis from the outlet of the metal chamber.

Description of the Drawings and Preferred Embodiments

Further features, objects and advantages of the present invention will become more apparent from the description of the preferred embodiment and accompanying

drawings in which :-

FIGURE 1 is a front schematic view of a preferred embodiment of the invention;

FIGURE 2 is a side view of the preferred embodiment shown in FIGURE 1;

FIGURE 3 is a schematic view of the holding furnace tilt control; and

FIGURE 4 is a graphic representation of the system variables during a simultaneous charging and casting operation.

FIGURES 5 & 6 are a schematic representation of a process which is an alternative embodiment of the invention.

Referring to the drawings, a holding furnace 1 is shown including a metal chamber 9 for holding molten metal, an outlet 7a for the supply of molten metal to a casting launder 7 and an inlet well 5 communicating with metal chamber 9. The holding furnace is tiltable about a pivot axis 4 to ensure that sufficient molten metal flows into the casting launder to maintain the level of molten metal in the launder at a predetermined height. An hydraulic cylinder 12 is provided on the opposite side of the furnace to the pivot axis to adjust the pivot angle of the holding furnace 1 and the inlet well 5 positioned on or adjacent the pivot axis 4 of the holding furnace 1. As a consequence of the positioning of the inlet well 5, the movement of the inlet well during the range of pivotal movement of the holding furnace is minimized.

The outlet 7a is preferably also positioned on or adjacent the pivot axis 4 of the holding furnace and arranged to communicate with the metal chamber 9 so that raising or lowering of the furnace tilt angle causes the level of molten metal in the launder 7 to rise or fall accordingly. To ensure that the motion of molten metal entering inlet well 5 does not excessively disturb the level readings in the launder 11, the inlet well 5 is axially displaced along the pivot axis 4 from the outlet 7a, and are preferably positioned at opposite ends of metal chamber 7.

During charging of the holding furnace, a charging means supplies molten metal to the inlet well 5. In a preferred form of the invention, the charging means is a transfer conduit 2, the upper end of which is below the level of molten metal

in a molten metal crucible 3. The transfer conduit 2 is arranged so as to be within the same plane as the pivotal axis ~ of the holding furnace 1. In this way, movement of the lower end of the conduit in the inlet well is minimized and movement of the upper end of the conduit 2a,2b,2c is rotational about the pivot axis in a single direction. Preferably the transfer conduit 2 rises above the level of molten metal in the crucible 3 to form a curved section which descends into the molten metal of the crucible.

To transfer the molten metal using the transfer conduit 2, the vacuum in the conduit is increased by engaging a vacuum line connected to a tapping in the curved section of the conduit. Since both ends of the conduit are below the respective levels of the molten metal, molten metal from the crucible rises up the conduit. As the molten metal rises up the conduit, the curved section of the conduit functions as a weir and because the level in the furnace is below that in the crucible, the metal flows from the crucible to the furnace inlet well. To maintain a flow of molten metal over the weir, the vacuum in the conduit is increased accordingly. Consequently the flow of molten metal from the crucible to the furnace inlet well can be controlled by adjusting the vacuum within the curved section of the conduit.

Once the crucible has been emptied, the transfer conduit can be raised to the position 2d to permit another crucible to be moved into position.

The inlet well 5 of the holding furnace is basically rectangular in shape. The width of the inlet well 5 should be no wider than necessary but sufficient to allow the transfer conduit to enter with some clearance to avoid contact with the refractory wall, even when the transfer conduit has accumulated a build-up of dross.

The length of the inlet well 5 is sufficient to allow the transfer conduit 2 to reach the bottom of the well, when the transfer conduit is lowered on its pivoting arm (not shown). At one end of the well, where the sloping discharge leg of the transfer conduit passes over the well wall, the refractory wall to a height which is above the molten metal level can be shaped to match the slope of the conduit, permitting the length of the inlet well to be reduced. The sloping refractory should only occur above the metal so that the full refractory thickness is available beneath the molten metal. The depth and shape of the inlet well bottom is important to

enable the discharge end of the transfer conduit to always remain well covered during the transfer operation and also allow the furnace to be almost completely emptied whilst leaving a small sump of molten metal with a sufficient volume to restart the transfer operation. The inlet well bottom should also be flat and sloped towards the furnace hearth so that it can be cleaned easily when the furnace is lowered. The depth of the inlet well bottom should also preferably be made so that it is dry when the furnace is fully lowered and when the furnace is itself about half full. This ensures that the extent of any dross and pot bath build-up is visible and easy to clean when the furnace is fully lowered.

The transfer conduit is shaped like an inverted "U" with the inlet leg vertical and the outlet leg sloped at a suitable angle, preferably about 45°. The conduit may be made from a single piece of cast iron and mounted on a separate rigid steel support arm (not shown) which enables the conduit to be raised and lowered simultaneously into the furnace inlet well 5 and the potline crucible 3 by a hoist (not shown) mounted on the furnace. The transfer conduit is guided against the front face of the furnace during raising and lowering by means of a guide arm mechanism (not shown) which limits lateral movement of the transfer conduit support arm.

To charge the furnace while casting is in progress, a potline crucible is placed on a fixed stand 8 located beneath the transfer conduit inlet leg. When the transfer conduit support arm is lowered, the transfer conduit inlet leg is submerged in the crucible to a depth of about 50 mm above the bottom of the crucible, whilst the outlet leg is about 50 mm above the bottom of the furnace inlet well. When in this position, the centreline of the siphon inlet leg intersects the furnace pivot axis 4 so that the pivot axis and the siphon are co-planar. This geometry is most preferable. In order to obtain an adequate metal flow, the crucible bottom should be at least 300 mm above the furnace metal level during casting. In the charging position, the vertical distance between the bottom of the conduit inlet leg and the furnace pivot axis should be minimized to limit vertical travel of the transfer conduit inlet during furnace tilt-back as charging takes place.

Furnace Tilt Control

The furnace tilt control mechanism is shown in FIGURE 3, the operation of

which will be described below.

During casting, the furnace 10 is tilted upwards gradually to maintain the level in the casting launder 11 at a constant level. This is done by controlling the hydraulic oil flow supplied to the furnace tilt cylinder 12 from hydraulic fluid reservoir 13.

A sensing device 14 which can produce an electronic signal proportional to the launder level delivers its signal to a control device such as a process computer 15 which manages a proportional feedback loop. The output signal from this control loop operates a proportional valve 16 in the furnace hydraulic circuit which delivers hydraulic oil supplied from a small hydraulic pump 17 to the furnace tilt cylinder 12. This proportional feedback control loop is referred to as the casting control loop.

A second proportional feedback loop controls the furnace tilt during charging. This loop receives input from the same metal level sensor 14 used in the casting control loop. This control loop is referred to as the charging control loop, the output of which controls a second proportional hydraulic valve 18 which affects the return of hydraulic oil from the furnace tilt cylinder to the hydraulic oil reservoir 13, thus controlling lowering of the furnace under its own weight.

During casting, only the casting control loop is active, the charging loop being inhibited. When it is required to charge molten metal into the furnace 10, the charging loop is made active and the casting loop inactive. This is handled reliably by the process computer 15 using the combination of two input signals. The first signal is the pressing of a button to initiate the charging operation by the process operator, and the second signal is when a small rise in the launder metal level is detected by the level sensor 14.

The charging control loop remains active until the end of the metal transfer. The end of metal transfer is determined by the process computer 15 when a sudden loss of vacuum in the transfer conduit 19 is detected by a pressure transducer. The sudden loss of vacuum indicates that air is being drawn through the inlet leg of the transfer conduit, signifying that the supply crucible (not shown) has been emptied. At the end of the metal transfer, the process computer 15 deactivates the charging

control loop and reactivates the casting control loop.

During the charging operation the casting launder level remains substantially constant. Thus the casting process can continue without interruption or significant variation.

Typical changes of the system variables with time are shown in FIGURE 4 during a "Charging During Casting" operation. In the graphic representation, the transfer conduit vacuum set point 20 is in kPa, the transfer conduit vacuum 21, in kPa, the furnace tile angle 22 in degrees, the furnace contents level 23 in tonnes of aluminium, the launder level 24 in centimetres, and the launder level set point 25 in centimetres.

At time A, the casting operation is supplied by a tilting furnace in the usual manner.

At time B, the transfer conduit has been positioned to enable the furnace to be charged and the vacuum line opened to reduce the pressure in the transfer conduit at a fast rate to save time. At time C, before the metal in the conduit begins to weir, the vacuum set point is changed to a slower rate to avoid the conduit filling with molten metal.

At time D, the flow of metal through the conduit into the inlet well of the furnace is detected as being greater than the flow out of the launder by a rise in launder level 24. At time E, the furnace begins to lower.

At time F, a sudden loss of vacuum is detected in the conduit resulting in termination of the transfer operation.

In an alternate embodiment of the invention, a holding furnace configured for charging by the use of the conduit may be operated in a batch process. The benefits of this embodiment relate to the ability to cast the furnace to its maximum tilt limit whilst sufficient metal still remains in the charging well to prime the conduit for refilling of the furnace. The amount of metal needed for priming the conduit in this embodiment may be less than 1 tonne, compared with 5 to 20 tonnes in a conventional arrangement.

In this alternate embodiment of the invention, the major benefits arise from the use of a conduit to charge the holding furnace, resulting in significantly reduced

losses due to dross formation, whilst enabling almost the full capacity of the furnace to be utilised in a batch type operation. The utilisation of as much furnace capacity as possible during batch casting operations is particularly important as it directly affects productivity.

As with the preferred embodiment, this alternative form of the invention requires that the metal in the furnace be maintained at a constant level in order to ensure that the conduit remains primed (discharge leg submerged in metal) during the charging operation. Since there is no need for very precise control of the metal level as in the preferred embodiment, a simpler method of controlling the furnace tilt may be used.

This method of furnace tilt control illustrated in Figures 5 & 6, does not require the use of a molten metal level sensor and does not require the molten metal to enter the casting launder, since casting is not taking place.

As shown in Figure 5 the furnace is firstly raised in the direction of arrow 20 until the molten aluminium remaining in the furnace reaches a visually predetermined depth (about 50mm below the furnace outlet 7a). The conduit is then lowered into both the furnace and the crucible as previously described, such that the discharge leg of the conduit in the furnace is sufficiently covered to eliminate turbulence, and there is clearance beneath the pipe for unhindered metal flow. A vacuum is applied to the conduit as previously described. (Figure 6).

Upon visual determination of a rise in the metal level in the furnace due to the onset of flow through the conduit, automatic lowering of the furnace in the direction of arrow 21 is commenced by manually initiating a computer controlled sequence. (Figure 6). The effect of this sequence is to cause the furnace to be lowered such that as metal flows into the metal chamber 9 of the furnace, the metal level in the furnace remains constant. The computer control sequence includes a "model" of the furnace refractory profile. This model consists of a table of values which relates furnace contents to furnace tilt angle and based on an assumed flow through the transfer conduit, a rate of tilt is calculated and translated to an appropriate opening of the hydraulic tilt control valve. The actual tilt angle is constantly compared with a target value after a small time interval and the hydraulic

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control valve adjusted to converge on the target value during the next time interval.

Termination of metal transfer occurs when a sudden loss of vacuum is detected by the pressure transducer as for the preferred embodiment.

At this point, (Figure 6) the conduit is removed and the whole charging operation repeated until the furnace is full, whence it can be used for casting in the conventional manner.

CLAIMS:

1. A method for supplying molten metal to a holding furnace tiltable about a pivot axis, said holding furnace having a metal chamber for molten metal, an outlet for discharge of molten metal from the furnace and an inlet well communicating with the metal chamber, said inlet well being positioned on the holding furnace on or adjacent to the pivot axis of the holding furnace, said method including the steps of, raising the holding furnace to tilt said holding furnace about said pivot axis until the molten metal from said metal chamber is present in the inlet well, inserting a transfer conduit into said inlet well, submerging the end of the conduit below the level of molten metal in the inlet well, charging metal through said conduit, controlling the level of metal in the inlet well by lowering the holding furnace thereby transferring molten metal into the metal chamber, and discontinuing the flow of metal through said conduit.
2. A method as claimed in claim 1, wherein said conduit supplies metal from a molten metal source above the level of molten metal in the holding furnace, said conduit being curved in an inverted U-shape to define a receiving leg and a discharge leg, said receiving leg being shorter than said discharge leg, the end of the receiving leg being submerged below the level of molten metal in the molten metal source, said conduit being connected to a source of vacuum and molten metal being charged through said conduit by increasing and controlling the level of vacuum in said conduit causing molten metal to rise up the receiving leg of the conduit and flow through the discharge leg of the conduit.
3. A method as claimed in claim 2, wherein the inverted U-shaped conduit is disposed in a general plane extending through the pivot axis of the holding furnace.
4. A method as claimed in claim 3, wherein the transfer conduit is held fixed relative to the holding furnace during charging so that the whole of the transfer conduit pivots about the pivot axis of the holding furnace.
5. A method as claimed in any one of claims 1 to 4, wherein said outlet of the holding furnace is disposed on or adjacent to the pivot axis of the furnace at a position displaced

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along the pivot axis from said inlet well and metal is discharged from the furnace outlet as metal is charged through said transfer conduit.

6. A method as claimed in claim 5, wherein the furnace outlet is connected to a casting launder through which metal is delivered for casting during transfer of molten metal in the inlet well being controlled by maintaining a constant molten metal level in the casting launder.

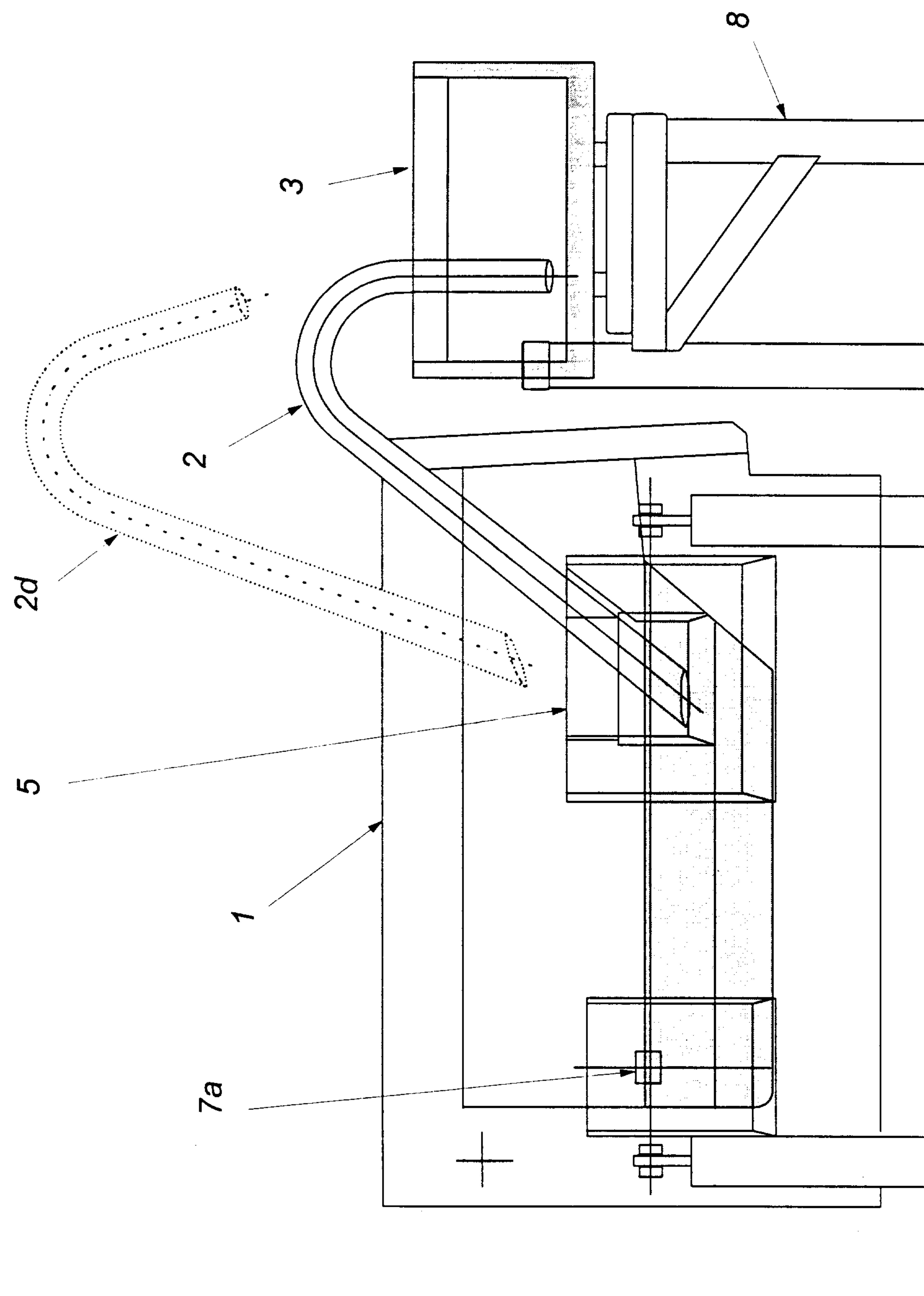


Figure 1

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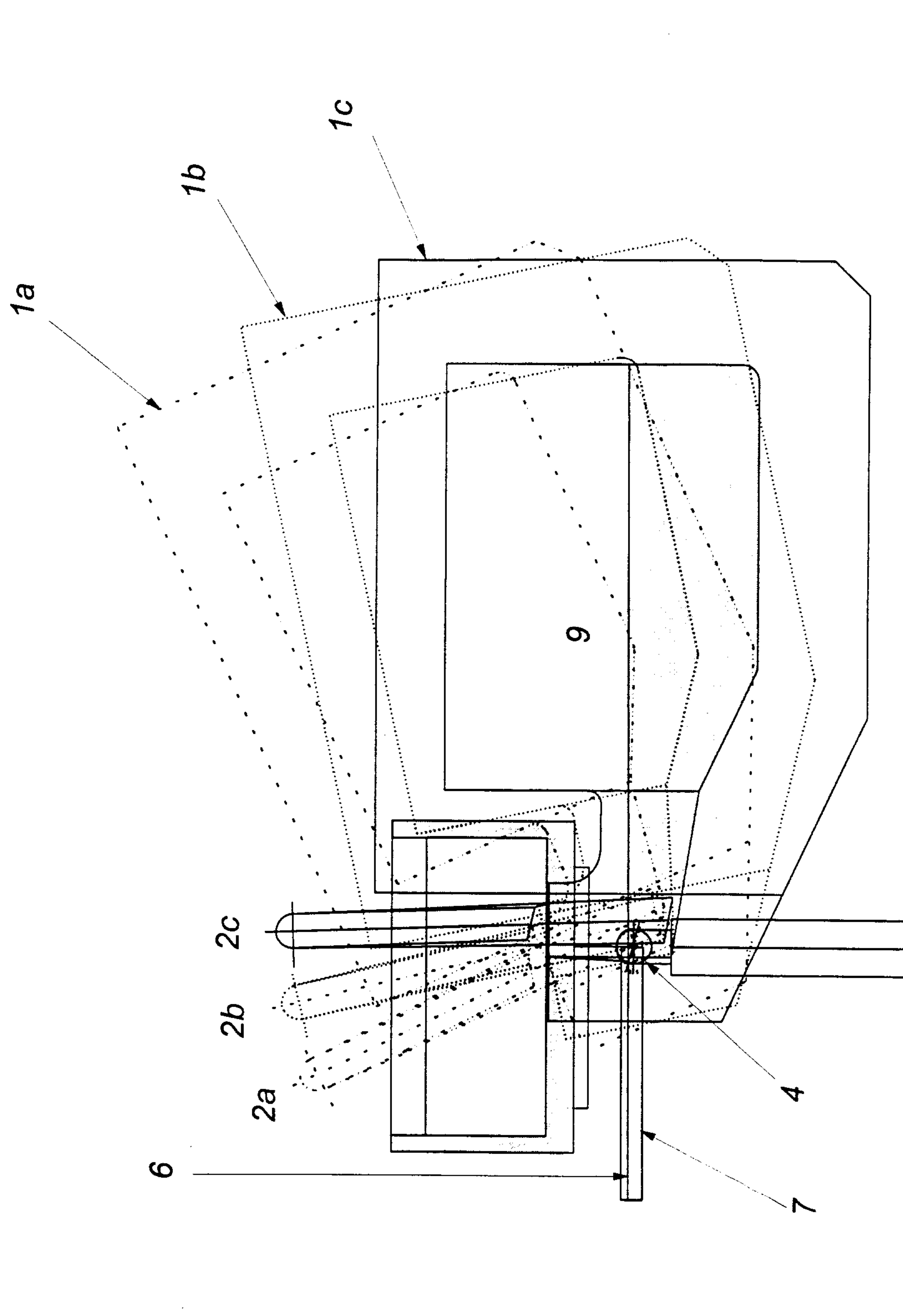


Figure 2

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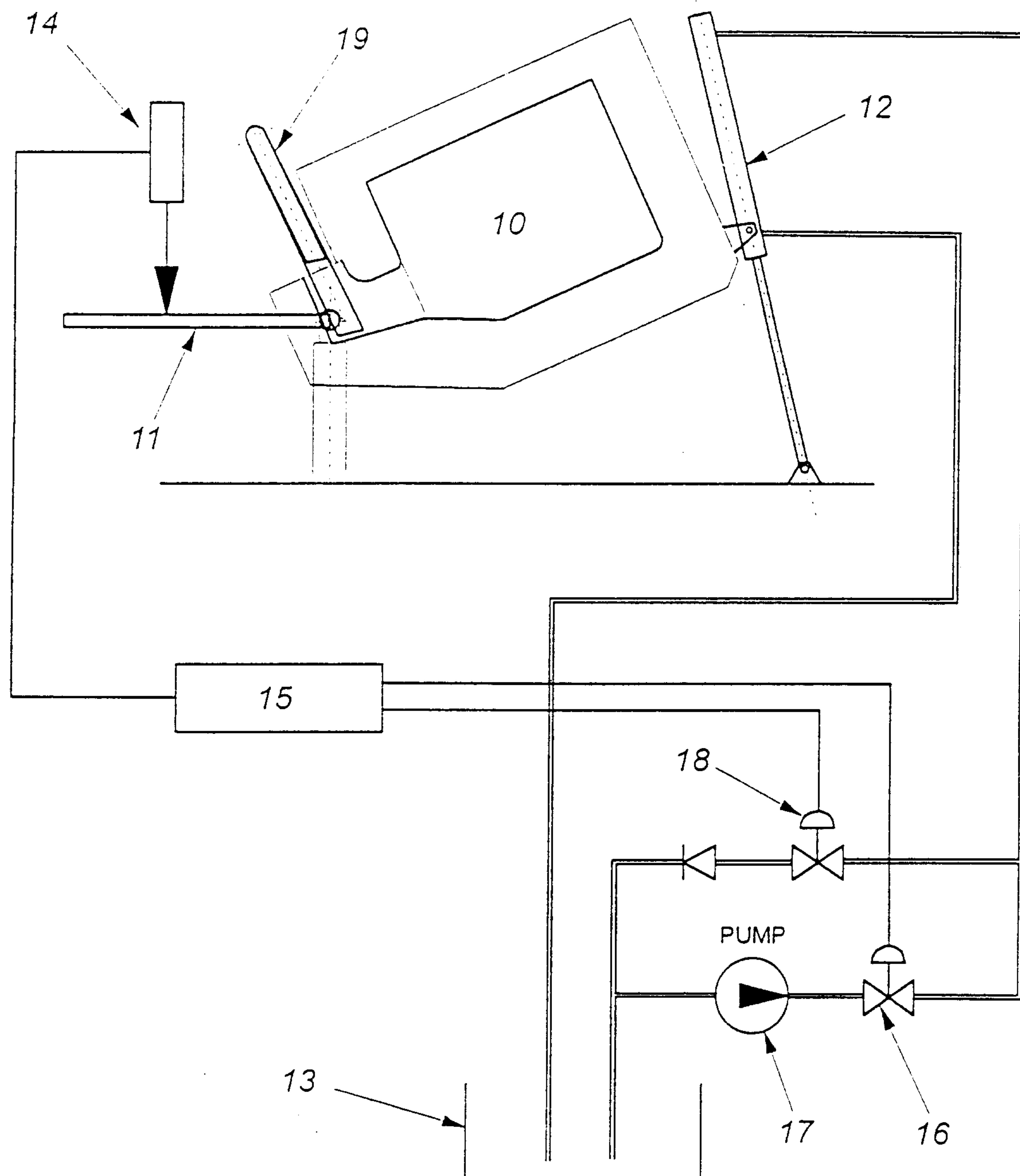


Figure 3

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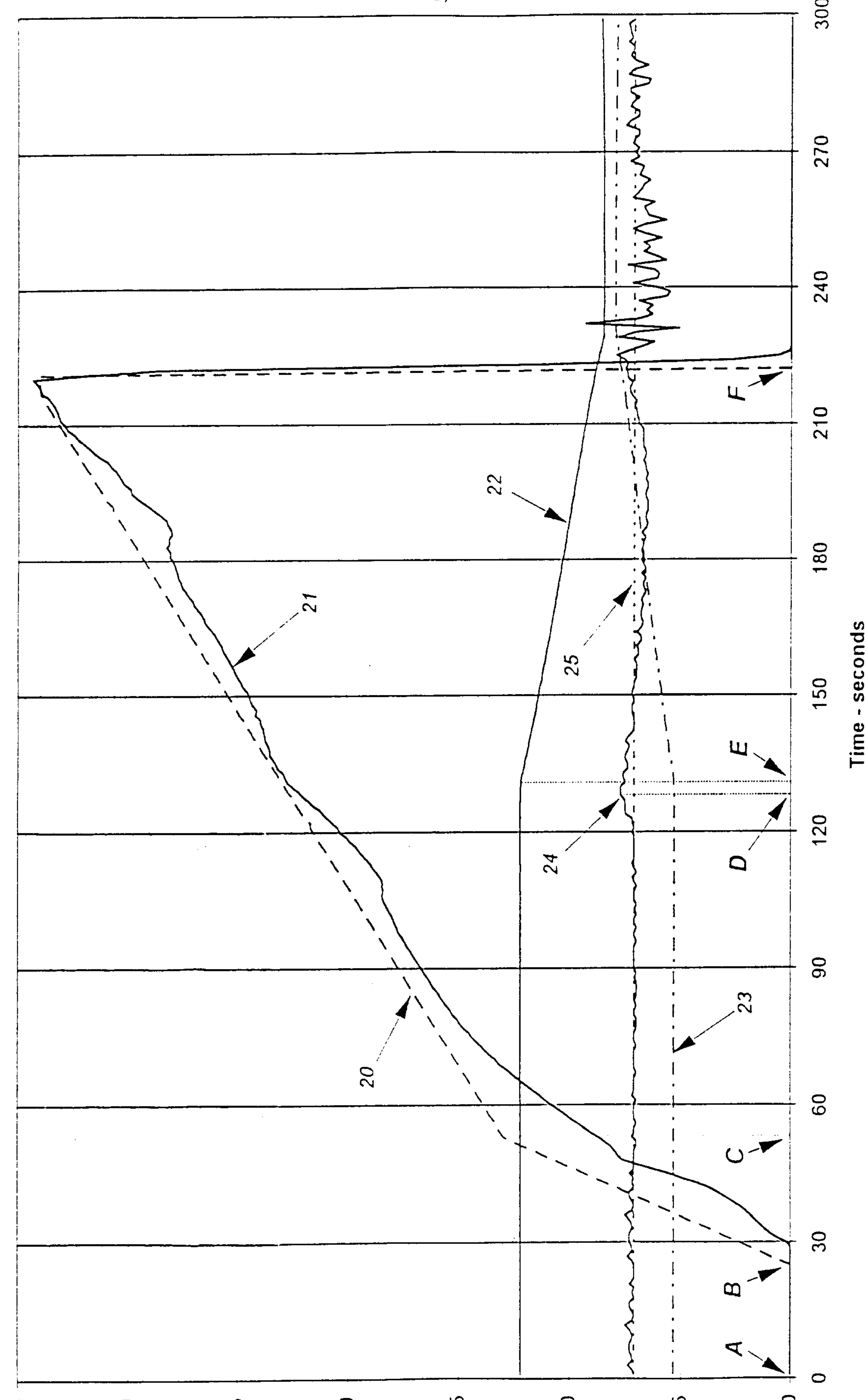


Figure 4

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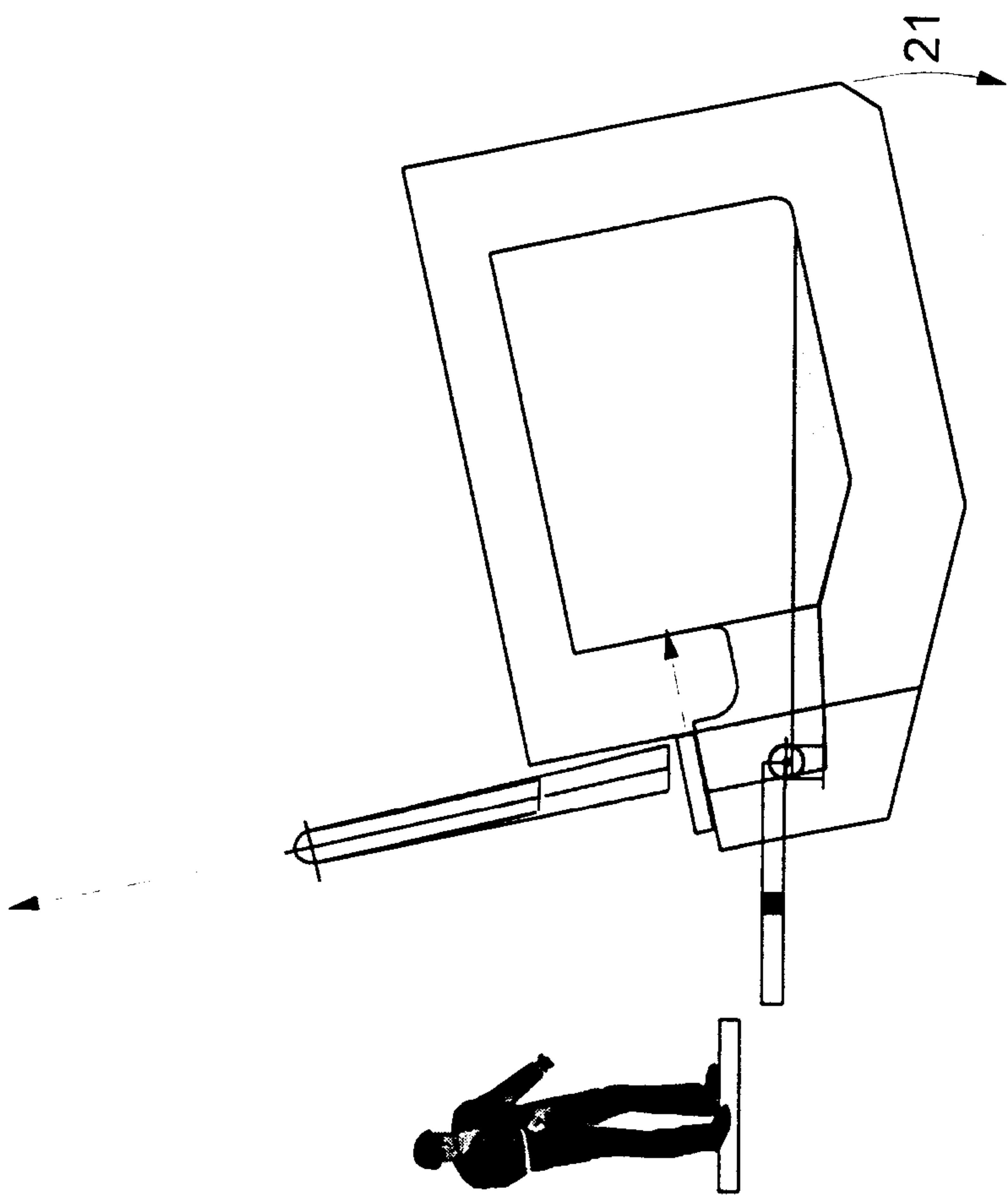


Figure 6

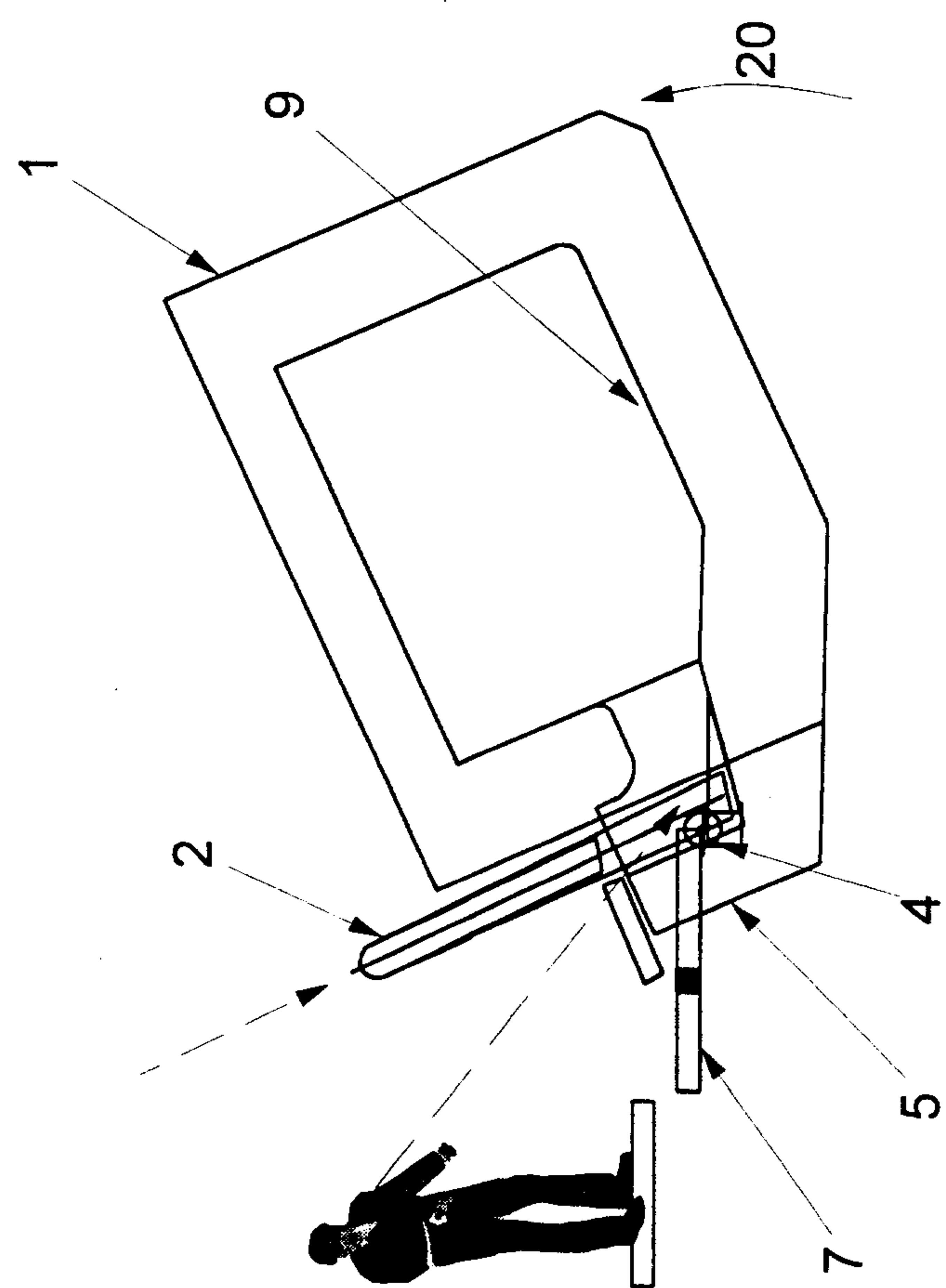


Figure 5

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